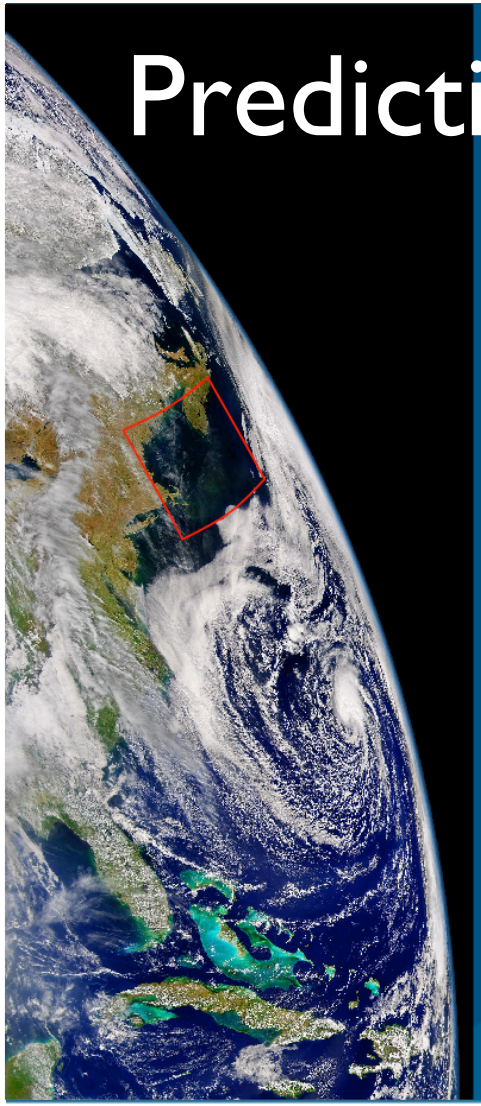
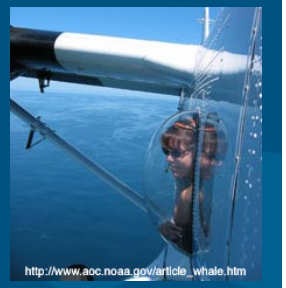
# Forecasting Changes in Habitat Use by Bowhead Whales in Response to Arctic Climate Change:

Pendleton, Holmes, Ferguson, Zhang,
Laidre, Monger, Moore, Pershing

# Predicting right whale distributions from space



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Cornell University

Gulf of Maine Research Institute
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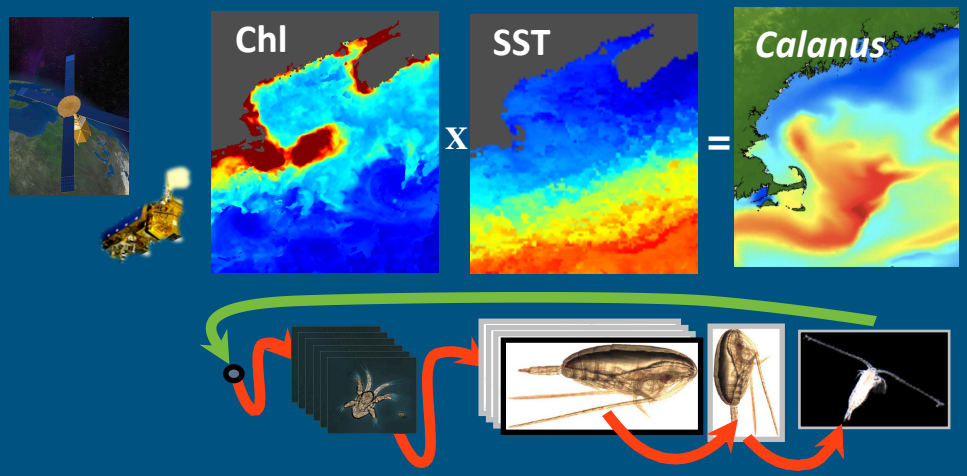
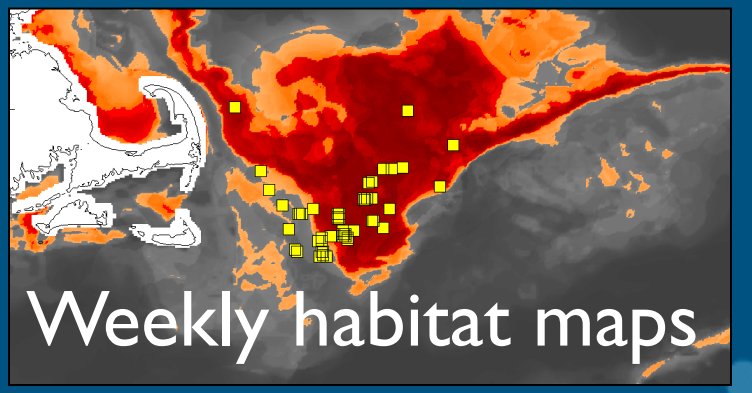



# Gen. I copepod models

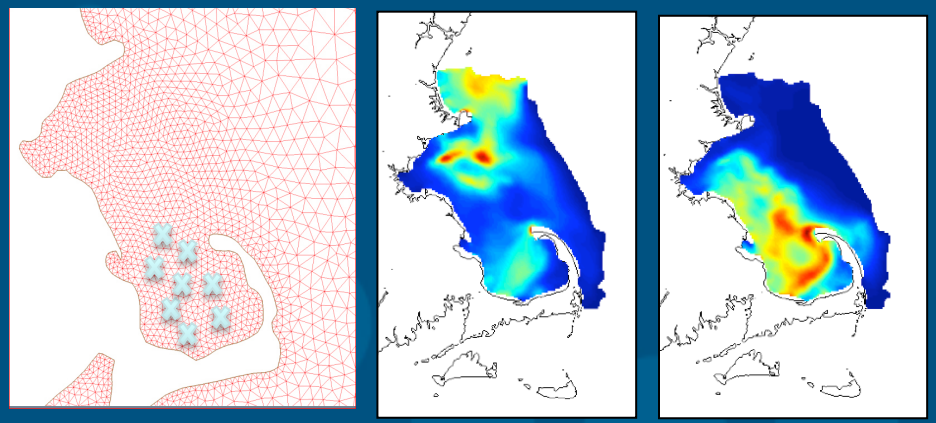
*Pendleton et al. (2009) Mar. Ecol. Prog. Ser.*
*Pershing et al. (2009a) Mar. Ecol. Prog. Ser.*
*Pershing et al. (2009b) Mar. Ecol. Prog. Ser.*




# SDMs with Gen. I copepod models

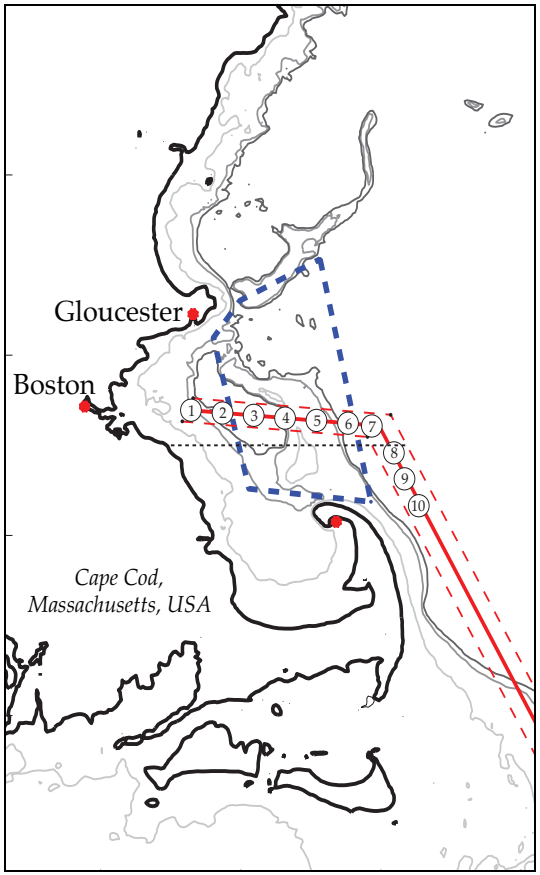
*Pendleton et al. (in press) Endangered Species Research*

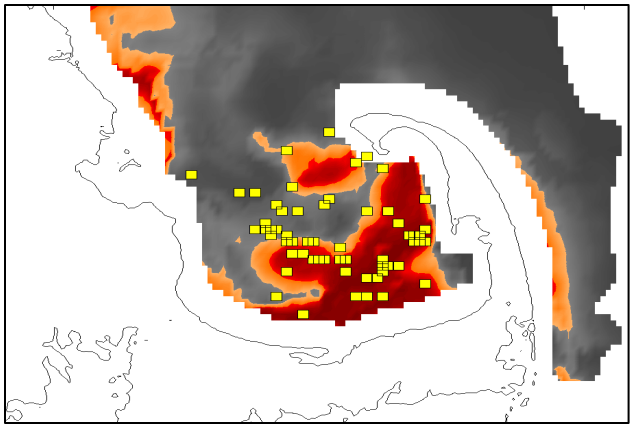
Finite Volume Coastal Ocean Model

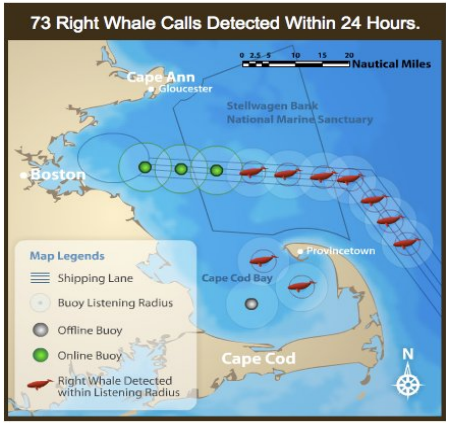


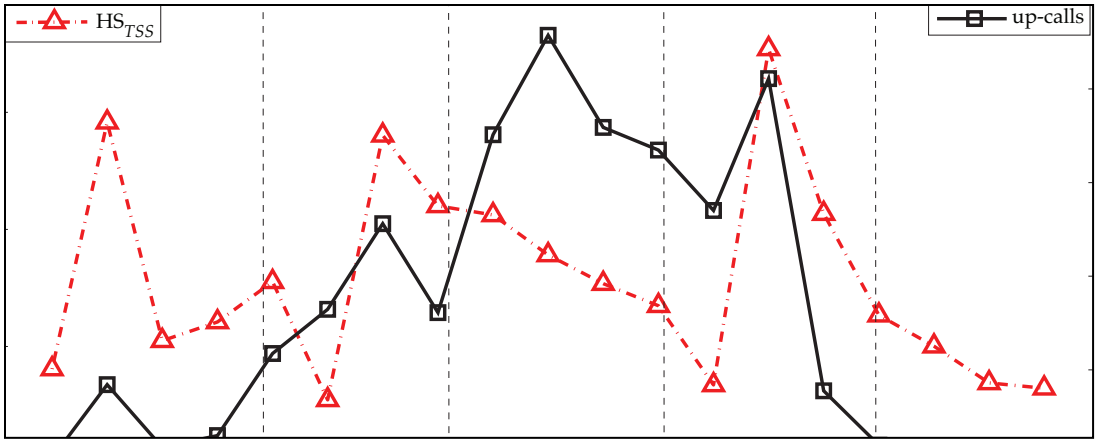
# Gen. 2 multi-taxa copepod models. SDMs with aerial and acoustic whale detections

# Acoustic validation



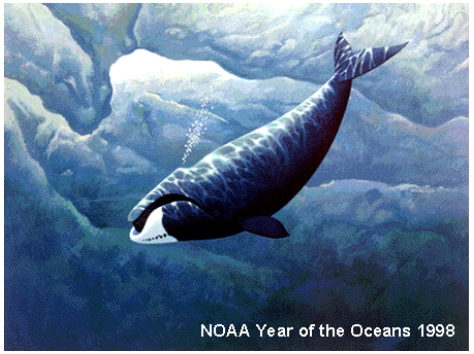


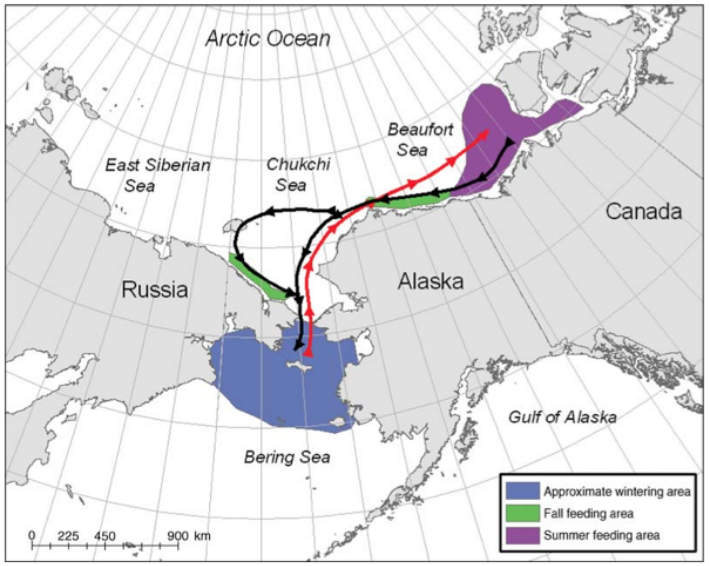




*See Clark et al. (2010) Marine Mammal Science*

# New Target: western Arctic Bowhead whales

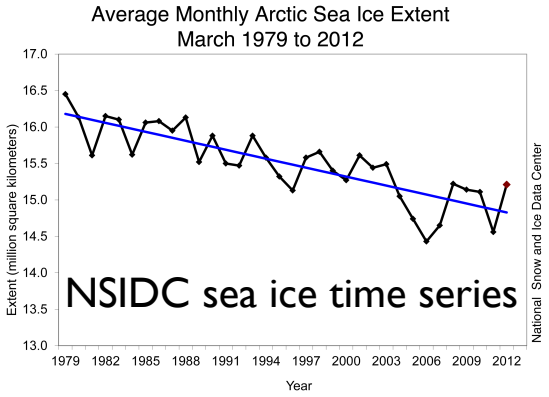
- Bowhead and right are baleen / filter feeders
- Similarly sized
- Both prey on calanoid copepods
- Whalers did not always distinguish

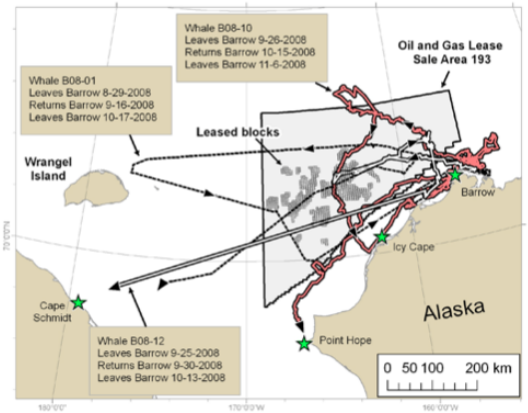


# Motivation

- Decreased ice extent
- Increased ease of access
- Increased pressure for offshore drilling & **seismic exploration**
- Unknown impact on marine mammals
- Legal: MMPA & ESA
- Conservation: Industrial scale impacts on “undisturbed” species




Quakenbush et al. ADFG / BOEM

# Objectives

- Bowhead whale hindcasts and forecasts
  - Hindcasts (‘88 on): Predict onto 5-year blocks
  - Forecasts: Biological-Physical model run to 2050 and used to drive SDMs
- Bowhead whale ecology:
  - Importance of Ice vs. prey
  - Impacts of commercial activity on whale / whale habitats

# Project phases

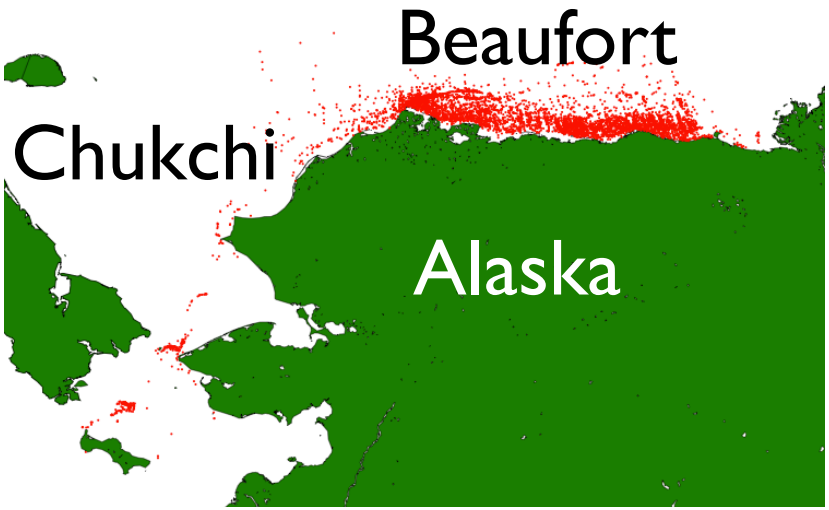
i. Development, data gathering and processing

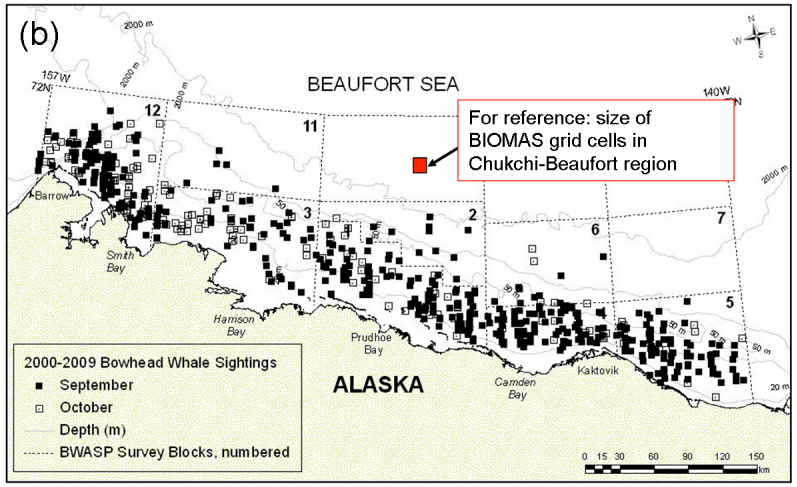
ii. Model calibration & validation

What vars are important? How? When?

iii. Using SDMs to test hypotheses concerning bowhead whale ecology

iv. Forecasting changes in bowhead whale distribution under ACC scenarios

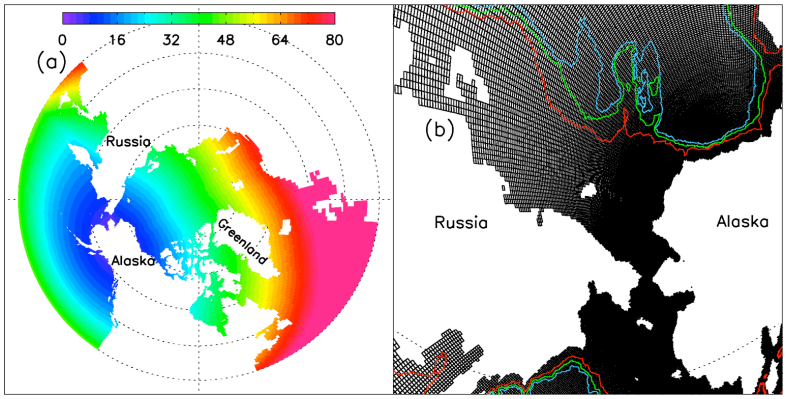


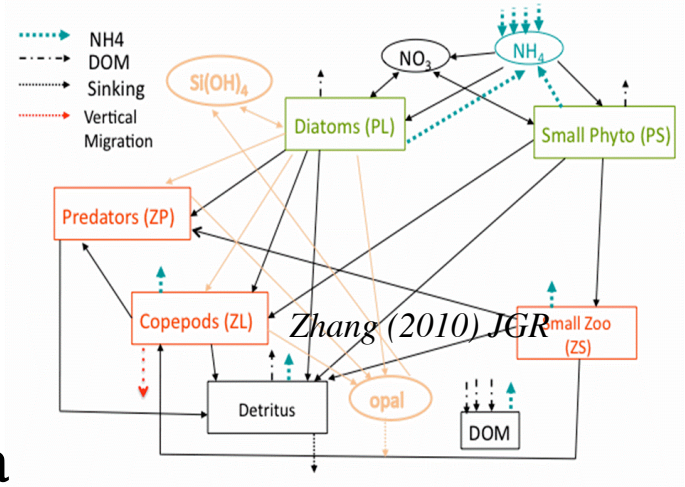

- Bowhead whale sightings Aerial 1988-Present
  - Acoustic recordings
- Biophysical Arctic ocean model BIOMAS
- Satellite SST, chl a, SSM/I sea ice
- Sound fields

# BIOMAS

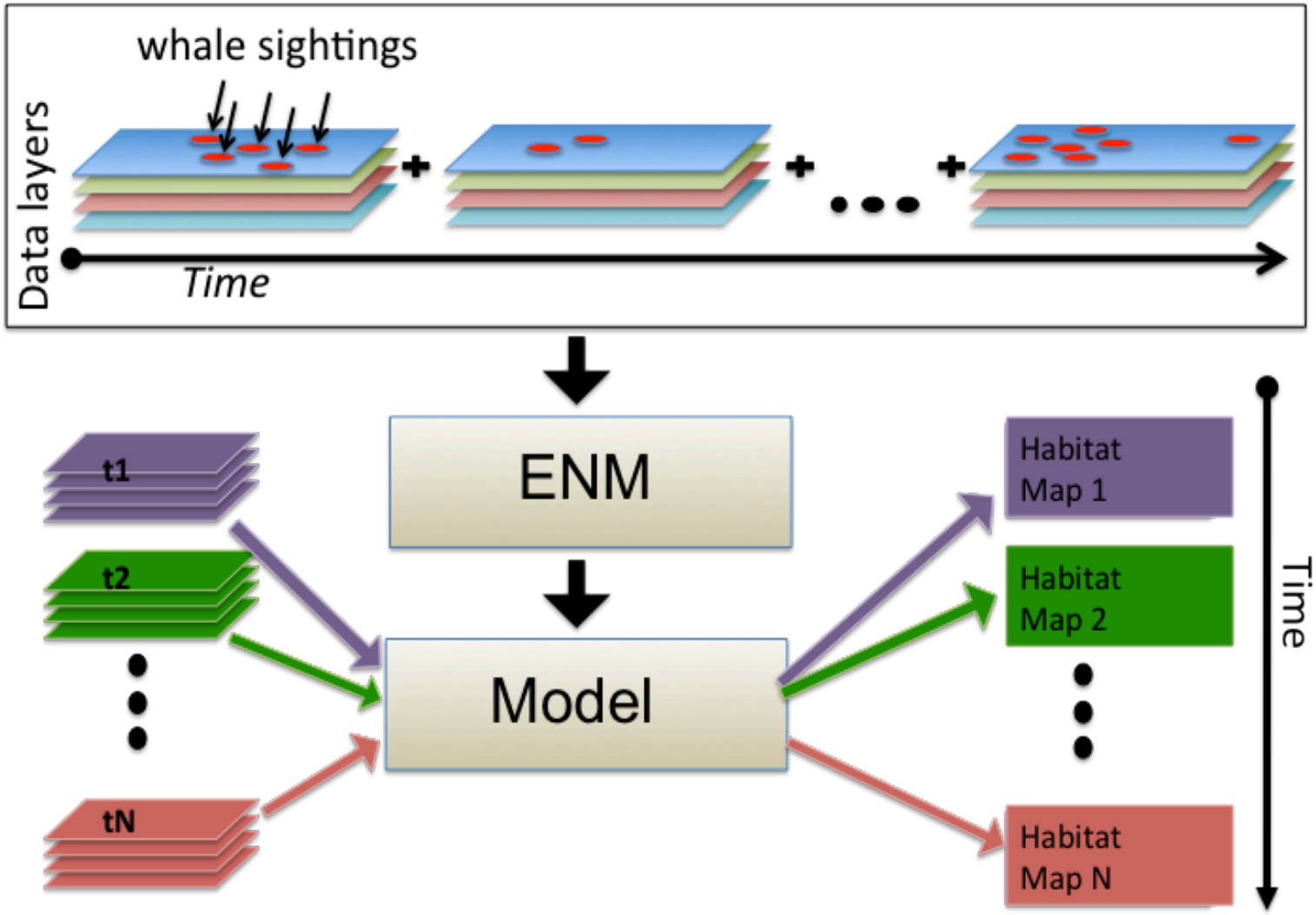
Biology/Ice/Ocean Modeling
Assimilation System




- Highest resolution (~4km) in Beaufort & Chukchi Seas
- Sea Ice model forced with atmospheric fields
- Circulation model based on the POP model
- 11-component pelagic ecosystem model
  - 2x phytoplankton
  - 3x zooplankton
  - Sea ice thickness
- Ground truthed with satellite data



# Technical Approach

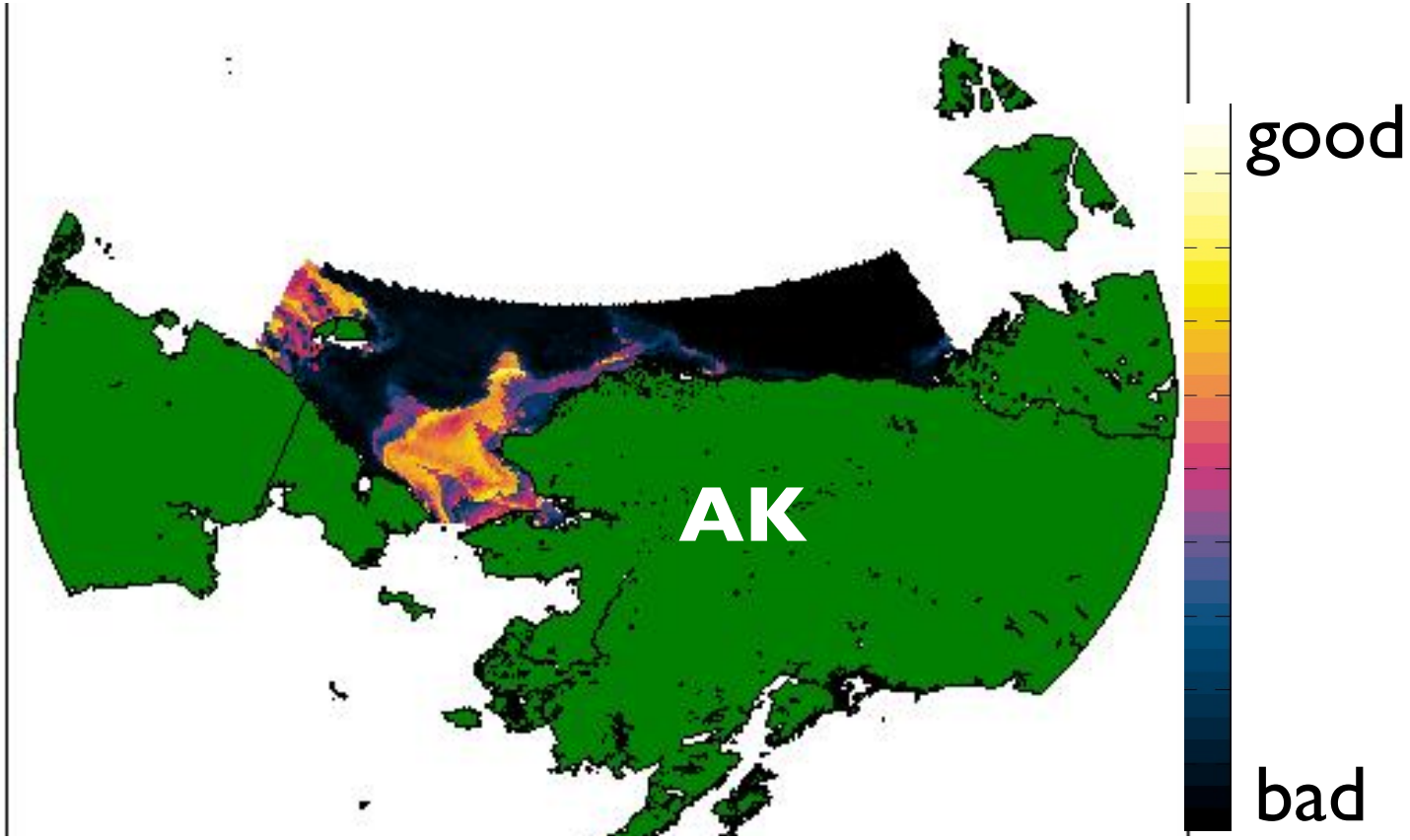


# June

Predictor Vars
Microzoo
Copepods
Euphausiids
Temp
Sea-ice

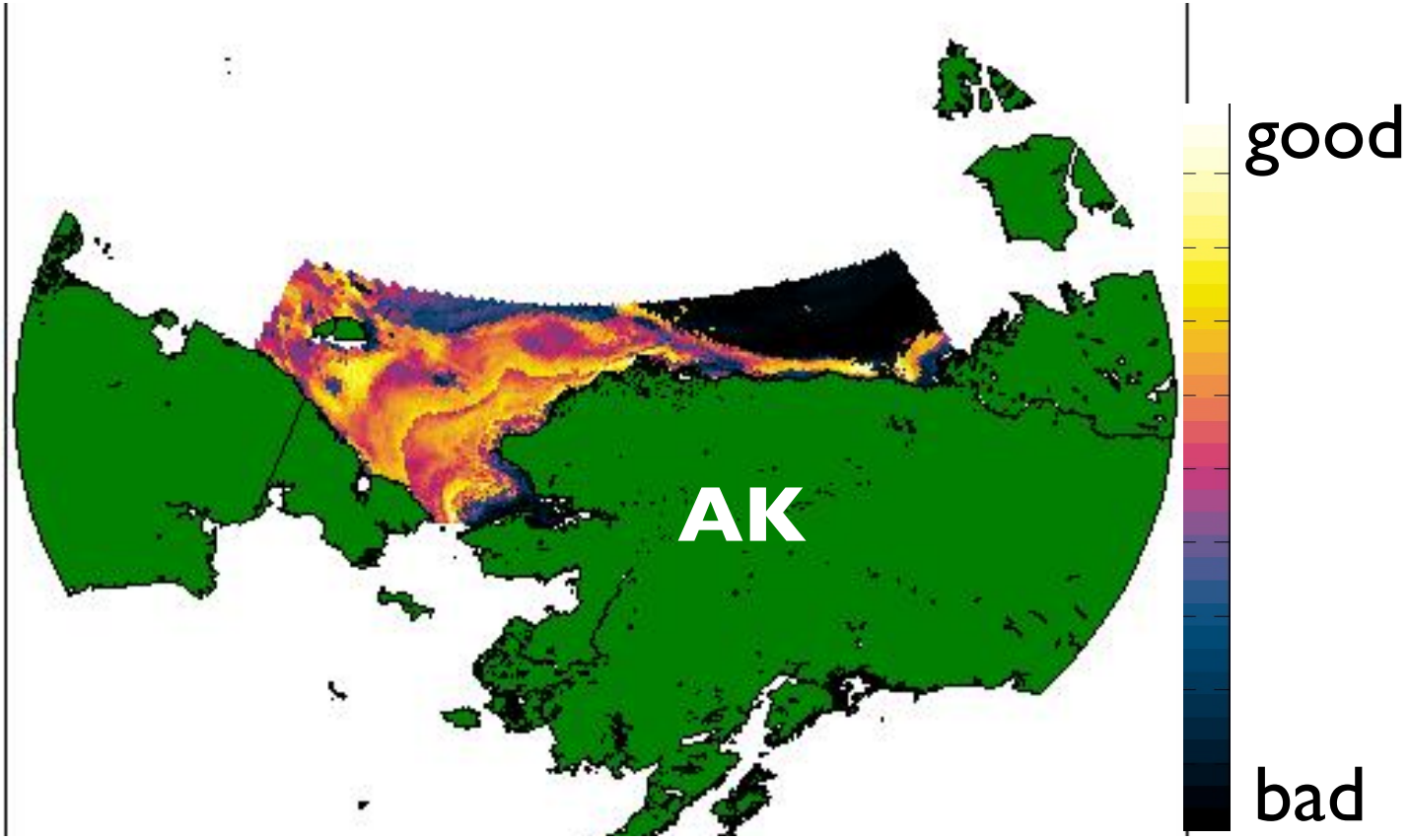
# July

Predictor Vars
Microzoo
Copepods
Euphausiids
Temp
Sea-ice



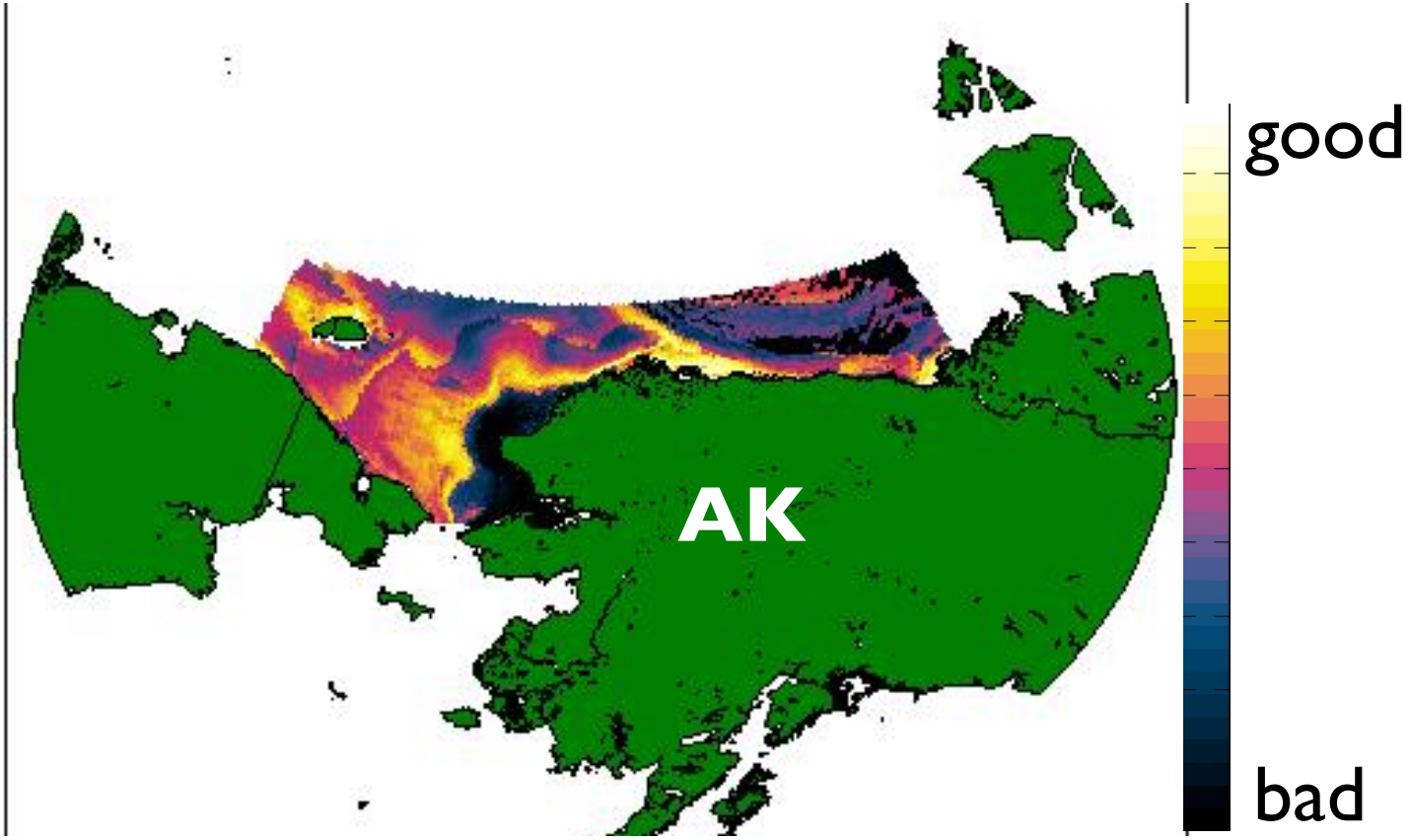
# August

Predictor Vars
Microzoo
Copepods
Euphausiids
Temp
Sea-ice

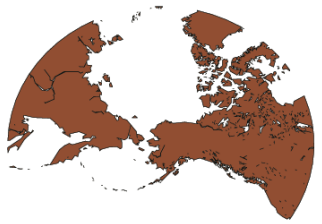


# September

Predictor Vars
Microzoo
Copepods
Euphausiids
Temp
Sea-ice



# October



Predictor Vars
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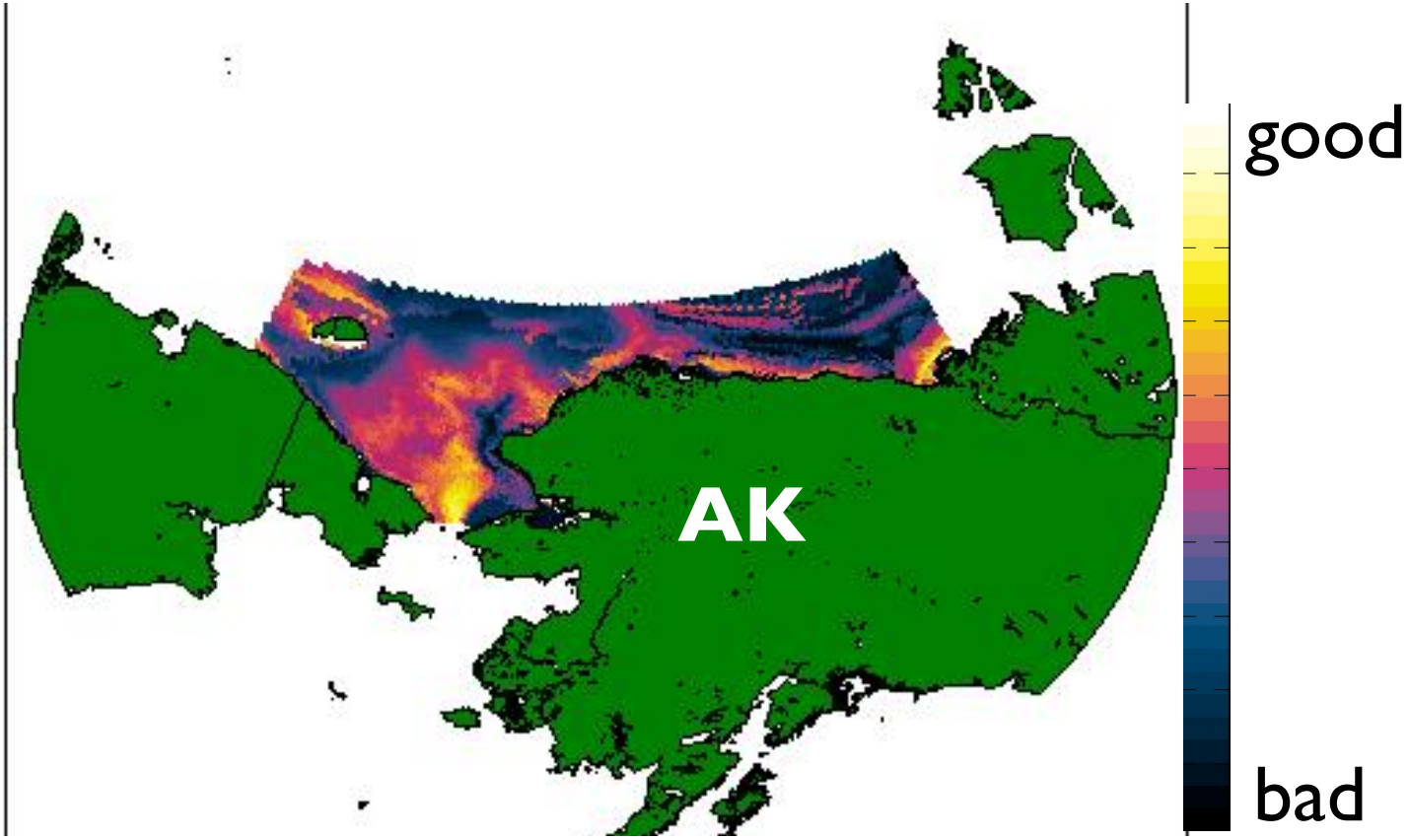
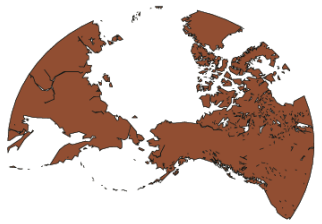


# November



Predictor Vars
Microzoo
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# Questions & Directions

- Relative influence of zoo layers
- Are models transferable?
  - Beaufort / Chukchi
  - North / South of Bering Strait
- Will whales utilize the Canadian Archipelago with increased ice free seasons
- How will decreased ice impact productivity and how will that impact whale distributions
- Bering Sea winter range where fewer data exist but there is more fishing

biology letters

Global change biology

*Biol. Lett.* (2012) **8**, 270–273
doi:10.1098/rsbl.2011.0731
*Published online* 21 September 2011

**The Northwest Passage opens for bowhead whales**

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